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A Note on Time Value in Spot and Forward Prices on the Brussels Stock Exchange

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Abstract

Until the mid-90s, the more active among the Brussels-listed stocks were traded in parallel segments: "spot" (that is, with $t + 3$ settlement) and "forward" (periodic settlement at the end of a two- or three-week period). The forward market was cheaper, deeper, unhampered by price limits, convenient also for shortsales, and played by the pros; so it looks likely to be the more efficient tier. In the forward markets, where the signal is stronger, we do find that time value affects prices. In spot markets there is very little evidence in favor or against a settlement effect, perhaps because the time value item has a very small variability. As expected, the time value signals are somewhat stronger in forward prices and noticeably so in forward premiums, but the estimates remain below our theoretical priors. We also find that price discrepancies are autocorrelated, probably indicating market inefficiency. A closer look reveals that positive forward premiums are persistent whereas negative ones vanish overnight. This is consistent with a market-imperfection explanation, where problems with raising cash (shorting money) are more important than problems with shorting stocks, thus creating preferred habitats for purchases (forward) and for sales (spot).

JEL G14, G15

Key words: dual markets, price discovery, settlement effect, microstructure

Time Value in Spot and Forward Prices on the Brussels Stock Exchange

Introduction

Until 1996, the Brussels Stock Exchange had two parallel trading tiers: a "spot" market tier with third-day delivery where all stocks were traded and, for the most active stocks, also a parallel "forward" tier with fixed-date delivery. The forward market was cheaper, deeper, unhampered by price limits, convenient also for shortsales, fully computerized, and played by the pros. Both segments were order-driven, and their opening prices were set via a call. So there were no firm bids and asks, implying that the usual no-arbitrage predictions about price differences should be weakened into statements about expectations.

A companion paper addresses the issue as to which market was noisier, that is, which acted as the price discoverer, during the period 1989-1996. In this paper we study the behavior of the spot-forward price differences or the forward premiums as they emerged, ex post, from the opening call. There are two issues of interest. First, we would expect a statistically clear time-value or settlement effect in the forward premiums, stronger and statistically more detectable than the settlement effects one expects in either spot or forward returns. The second issue is whether the forward premiums are consistent with the notion of market efficiency, where prices are unpredictable, or at least, price discrepancies across markets are.

Our results on settlement effects are mixed, at best. In the spot market we actually see very little evidence in favor or against a time-value effect, consistent with our priors on the power of the tests. In the forward markets, where the time value signals should be stronger, we do find that time value affects prices, but the effect is substantially smaller than what theory predicts. As expected, time value is noticeable in forward premiums, but even there the estimates remain below our theoretical priors—and, indeed, below the results for forward returns. Next, we move to the autocorrelation issue. We find that forward premiums are anomalously autocorrelated, arguably a sign of market inefficiency. This then raises the question why traders do not react to these predictable price anomalies. A closer look at the price discrepancies reveals an asymmetry: unusually positive forward premiums are the ones that tend to persist for a long time, while abnormally negative ones vanish overnight. In addition, large positive forward premiums are about four times as frequent as large negative discrepancies. This pattern is the opposite of what one would expect if the problem had been a lack of shortselling in the spot market. Instead, the anomaly suggests a cash-is-king effect, that is, problems with raising liquidities, steering buyers towards the forward market and sellers to the cash market, thus creating episodes of persistently high forward premiums.

The rest of the paper is organized as follows. Section 1 describes the markets and the data. In Section 2 we start from a standard noisy-price model and derive, discuss, and test alternative tests for settlement effects in, respectively, spot returns, forward returns, and forward premiums. Section 3 provides the tests for autocorrelation; we also show that the lack of efficiency is not related to difficulties in going short but rather to simple financing considerations. Section 4 concludes.

1 The Two-Tier Brussels Stock Exchange: Institutional Background

Brussels used to have not only its own stock market (the Brussel Stock Exchange (BSE), since 2001 integrated into Euronext), but even a two-tiered one: a "spot" market tier with third-day delivery, and for the most active stocks a parallel "forward" tier with fixed-date delivery. There used to be twenty-four fixed such settlement dates per year, implying that the trading periods typically lasted about two weeks—hence their name *quinzaine*, two-week period.[1] Details about the market organization are crucial for our analysis. In this section, we describe the price mechanisms in the forward and spot market and the delivery rules as they applied during the sample period.

1.1 The price mechanism in the forward tier

The forward market used to work via a pure public limit order book (which, during the sample period, was kept by a version of Toronto's Computer-Aided Trading System, CATS). Thus, although brokers were allowed to trade on their own account, they did not act as market makers, and their main role on the floor was to pass on the orders from the public to the exchange. At 9 p.m. the one-hour pre-market started, during which orders could be added

[1] The forward market has now disappeared, following an EU-directed "$T \leq t + 7$ days" rule implemented in the 1990s. London used to have a two-weekly fixed-delivery system too, Paris had delivery at the end of the month in its "forward" section for big stocks. (There also was a spot section for small stocks). Basel offered the choice between several delivery dates.

Table 1: **Tick Size in the Spot and Forward Market**

price range	price must be a multiple of	minimal percentage price change at lower end of scale	minimal percentage price change at top end of scale
BEF 1-500	1	100%	0.20%
BEF 502-1,500	2	0.40%	0.13%
BEF 1,505-5,000	5	0.33%	0.10%
BEF 5,010-10,000	10	0.20%	0.10%
BEF 10,025-50,000	25	0.25%	0.05%
BEF 50,050	50	0.10%	—

Key One BEF is approximately EUR 0.025.

or withdrawn and CATS displayed a continuously updated preliminary market-clearing price. Actual trading in the forward market started at 10 a.m., with a simultaneous call market for all stocks. That is, at 10 a.m. limit orders were matched as far as possible, and executed. For most stocks the opening represented a substantial part of the day's turnover. After the opening round, the interactive trading session or "continuous market" started (10:00-16:30). Throughout the continuous-market session, the four best unfilled limit orders on the buying and selling side were displayed on computer screens and could be taken up by any incoming new order. Only brokers saw the screens: at the time of the sample, individual investors just heard (or saw) the opening and close prices over the radio or on Teletext, at noon or in the afternoon. Orders could also be matched directly, between brokers or in-house, provided that the price was within the book's bid-ask spread and the trade was reported immediately to the exchange. Large trades, *i.e.* blocks of at least BEF 50m (EUR 1,250,000) could be crossed or traded outside the BSE (often in London or Paris), but had also to be reported immediately. There were no limits on consecutive forward price changes. Limit order and trade prices were rounded according to a schedule shown in Table 1. Until the 1996 reform, the exchange's minimum margin requirement for a forward trade was 25 percent, but the BSE left the enforcement of this rule to the individual brokers (who bore the default risk). Securities could be posted as margin; in fact, many investors left most or all of their stocks with a their broker—most shares are bearer securities—and used this portfolio as margin for forward positions. Thus, there was no opportunity cost associated with the margin.

Prices for all traded lots were shown, in sequence (but not time-stamped), in the official price list, later *De Tijd* and *L'Echo de la Bourse*. In the electronic records, only open/close/high/low are available.

1.2 The Spot Price Mechanism

Due to its lower volume, the spot market was fully computerized much later (in 1996). Like the forward tier, it was order-driven, but the implementation was fairly different. First, there was no pre-market, so that the opening price was potentially much more subject to noise than the forward opening price even apart from volume effects. Second, because of the thinness of the market, for most stocks there was just one trading round per day. A continuous market existed only for the more active stocks (quoted on the *"corbeille"* segment), and even this continuous market was not very active.[2] Third, there was no centralized public order book kept by the exchange. Rather, a few specialist brokers each kept their own books, and met sometime between 1 and 1.30 p.m. on the Exchange's floor to aggregate their information and identify the price that maximizes trade from the combined order book. Fourth, for stocks that were not traded on the parallel forward market there were overnight price limits of 5 percent (for very thinly traded stocks, traded on the *parket* segment) or 10 percent (for other stocks, traded on the "*corbeille*" market); and, in the *corbeille* market, subsequent intraday price changes could not exceed 5 percent.

The actual pricing and trading was organized by a BSE official, who started by crying out a price proposal. This price proposal equaled the price that maximized trade from the order book if that price was within the price change limits; if not, the official announced the price limit itself. In addition to the price proposal, the official also announced the direction of the imbalance. If there was an excess supply (demand) at the proposed price, additional purchase (sale) orders from the floor were solicited to reduce the imbalance in the book. If the remaining imbalance between supply and demand at the price limit was less than 50 percent, the specialist would decide to 'reduce' most or all orders on the excess side, *i.e.* execute only part of each order; the transaction price was then published in the financial press with the qualification *"sellers reduced"* or *"buyers reduced"*. If at the price limit the imbalance between supply and demand remained huge even after soliciting orders from the floor, there was no trade at all, and the price limit was published as an indicative price. In practice, however, when the imbalance was only slightly larger than 50 percent the stock's specialist brokers often added buy or sell orders for their own account to prevent no-trade (and no-income) days.

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[2] For stocks quoted on the *corbeille*, the fixing was followed by the traditional (blackboard-and-chalk) version of the continuous market: unfilled orders were chalked onto the blackboard and could be picked up from the floor, and orders could also be matched directly on the floor at a price within the book's spread.

As, around 1990, the spot market list contained about 300 stocks, the stock-by-stock opening-call prices were set more or less sequentially; the exact timing of each stock's spot fixing was not registered. For the *corbeille* market, prices for all traded lots were shown, in sequence (but not time-stamped), in the official price list but in the electronic records, only open/close/high/low are available. For the *parket* stocks there is just the single price.

1.3 Settlement Rules

For the BSE, the other details of the actual settlement were similar for both market tiers. The buyer payed via a bank transfer rather than by check. This means that there was no "mail float" on the payment side. Still, the value dates for buyer and seller did not match perfectly: the buyer's value date is one day before the actual settlement day, and the seller obtains value one day after settlement.

Delivery of the stock could mean actual physical delivery of the piece of paper that represents the bearer share, if the buyer desired so. Alternatively, the buyer could ask that his or her purchase be recorded with a netting and depository institution, the *Caisse Interprofessionelle/Interprofessionale Kas* (CIK). The CIK merely netted the physical deliveries across brokers if actual delivery was asked, and held the paper on behalf of investors that did not demand physical delivery. Thus, the CIK was not a clearing house in the usual sense: it did not act as a central counterpart, nor did it cancel an individual investor's earlier purchases against subsequent sales (or *vice versa*) within one settlement period. There was some informal clearing by brokers, though: brokers did not exact delivery and payment for a forward transaction that was reversed later on via the same brokerage house and within the same quinzaine.

One function of the forward market, therefore, was to reduce the cost and hassle of mutually offsetting stock deliveries and payments for trades that had been closed out within the same quinzaine. This partly explains why, unlike in currency markets, in the forward tier the transaction costs for small trades were somewhat lower than in the spot tier (as illustrated in Table 2).[3] A second useful feature of the forward tier is that it allows one to take short positions until the end of the quinzaine, positions that could then be rolled over fairly easily. In Belgium, there was no formal legal framework for asset borrowing and spot short-selling

[3] Another reason for the lower transaction costs might have been the fact that the forward market tended to have larger volumes than the spot market for the same stock.

Table 2: **Transaction costs, spot and forward, 1990**

item	cost of spot trades	cost of forward trades
BSE Commission	0.03%, max BEF 6 000†	
Transaction Tax	0.17%, max BEF 10 000	
Brokerage fees		
- fixed part	BEF 200*	
- variable part:		
order BEF 1-5m	1%	.8%
order BEF 5-10m	.8%	.6%
order BEF 10-20m	.4%	.3%
order BEF 20-30m	$\geq$ BEF 130 000‡	.2%
order $\geq$ BEF 30m	$\geq$ BEF 130 000‡	$\geq$ BEF 120 000‡

† : 40 BEF is worth approx. 1 EUR; * : plus BEF 100 for the buyer if physical delivery is asked; ‡ : negotiable, with the stated amounts as minima. Thus, a smallish trade of BEF 250,000 (approx. EUR 6.250) would cost 1.29 percent spot, and 1.09 percent forward. For an order of BEF 30m, the cost difference may be as small as 10,000/30,000,000 = .033 percent.

until the 1991 Stock Market Reform Act, so until then the forward market provided the sole organized opportunity for short positions. A third function of the forward market was to provide the equivalent of buying on margin: the actual payment was deferred until the end of the *quinzaine* (at which moment the forward contract could be rolled over), and the buyer just posted the 25 percent security. Since leveraged buying was possible in the forward market, no organized system of buying on margin was set up in the spot market.

1.4 Taxes

A last relevant detail is income tax. For brokers or corporations, all interest received or paid and all short-term capital gains or losses are fully taxable or deductible. So if brokers or corporations dominate the market in the sense that they are systematically the marginal traders, taxes are neutral. Under personal taxation rules, capital gains or losses are neither taxable nor deductible; nor can one deduct interest costs incurred to finance short-term trades; and interest income is *de facto* taxed at the withholding tax (10 percent at the time). In short, also for private persons the gross rate is the relevant interest rate, unless the marginal traders are buyers of stock for whom the opportunity cost is the interest foregone on a deposit.

Dividends are largely tax-exempt for corporations; for individuals, a 25-percent withholding tax applies. Unpublished tests show that the average price drop on ex-dividend day was equal to the dividend net of the withholding tax—20 percent before 1984, and 25 percent thereafter. All returns are accordingly computed from dividends net of withholding taxes.

We conclude the descriptive section with some information on the data.

1.5 Data

The sample period starts early 1989, at which time the forward markets was fully computerized, and ends in 1996; in 1997 the forward market disappeared. Euronext's historic-data CDs for that period include the opening spot price per day, and, for the forward market, the daily opening, high and low, and close price. Data on dividends, bonus dividends, splits, and rights issues[4] were missing, and were hand-collected from *Memento der Effecten*, a trade publication, and from *De Tijd*, which published the Dutch-language version of the Official Price List. For the risk-free rate we used the Euro-BEF 1 week middle rate from Datastream.

We discarded foreign stocks, about half of the list, since price discovery for these shares probably happens abroad anyway. So we started from data on 119 Belgian stocks traded on both the spot and forward tiers of the Brussels Stock Exchange during the period 1989-1996. Some data cleaning was required: 16 stocks are excluded due to an insufficient number of observations (too many missing data points), 31 stocks are connected to other shares due to a change in the name or code after a stock split or merger. Thus, 72 stocks remained. All unusually large forward premiums or large change in the prices were double-checked with the prices posted on the hard copies of *De Tijd*, including the next-day rectifications for typos. All prices that are indicated 'sellers reduced', 'buyers reduced', or 'indicative', were considered to be missing observations. Whenever there is a missing price, the two returns that are associated with that price are missing too. That is, we never use cumulated returns straddling some missing price.

Eight years of data means over 2000 trading days. The number of effectively available observations is very variable, ranging from below 50% to 100%. There is a clear relation with market activity. As can be seen in Table 3, the firms in the bottom third, by turnover, on average trade only 75 (spot) or 60 (forward) percent of the time. Forward markets more often have missing prices than spot markets, despite their higher turnovers and the absence of price limits; this probably reflects the interventions by the spot market's specialists mentioned in Section 1.2. There also is a strong negative relation between turnover and return variance,

[4] A subscription right is represented by a coupon designated for the purpose, and is traded separately the moment the stock goes ex this coupon. The market values of these "scripts" are very noisy so we worked with the standard instrinsic value of a subscription right.

Table 3: **Trading Frequency and One-day Return Variance across Turnover Classes**

sample	number of returns		Average Variance		Median Variance	
(by turnover)	Spot	Forward	Spot	Forward	Spot	Forward
All	95,591	87,549	3.26	3.43	2.23	1.91
low turnover	27,576	21,686	4.55	5.17	2.77	2.11
medium turnover	31,169	29,197	3.23	3.12	1.92	1.66
high turnover	36,848	36,670	1.99	2.00	1.61	1.88

Key Each turnover class contains 24 stocks, and ranking is done on the basis of average daily turnover.

prima facie, as also illustrated via Figure 1. Much of that, however, seems to be due to the outliers: when we consider medians the schedule is much flatter.

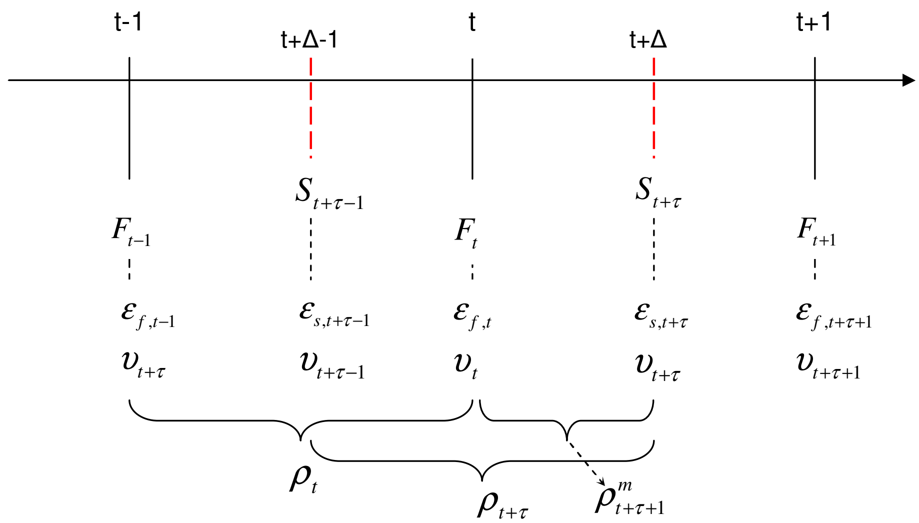
2 Verifying the Settlement Effect in Prices In Well Integrated Markets

The fixed-lag and periodic settlement systems, as adopted by the spot and forward markets, respectively, should each generate a specific type of seasonal in the observed stock returns. In the fixed-date ('forward') markets, consecutive prices within one settlement period are essentially forward quotes with decreasing times to maturity, as shown in Table 4 below. It follows that, within a given settlement period, the percentage price change corresponds to an (unobservable) spot return minus approximately the daily risk-free rate;[5] that is, percentage price changes within a given settlement period should tend to be below the general average return. On the other hand, there is a substantial change in time to maturity between the last price of a settlement period and the next day's price. Thus, the percentage change that straddles two adjacent settlement periods should consist of a true spot return plus two weeks' (London) or one month's (Paris) worth of time value, and tend to be above the general average return. Solnik (1990), and Crouhy, Galai and Keita (1991) document such an effect for the French market. Solnik finds that the stock market index behaves as predicted, but on the individual-stock level Crouhy, Galai and Keita find evidence of overreaction, especially for thinly traded securities. Jaffe and Westerfield (1985) and Condoyanni, O'Hanlon and Ward (1987) report anomalous results for the London market.

Spurious seasonals caused by time-value effects should also be observed in markets with

[5] This claim is exact only if riskfree rates are constant across maturities and over time.

Figure 1: **Asynchronism of Spot vs Forward Prices**



Key t is at 10:00 am and $t+\tau$ is at 13:30 p.m.

a fixed-lag delivery system. As 'days' refer to working days rather than calendar days, any intervening weekend or holiday should lead to time-value effects in prices. As Solnik (1990) notes, there is often a day-of-the-week effect; but its size is

> *"... usually much larger than the expected effect of the settlement procedure, and often does not take place on the expected day.*[6] *This implies that the observed day-of-the-week effect is explained by other phenomena and that the influence of the settlement procedure is too small to be detectable without a precise model of these other phenomena."*

McFarland, Pettit, and Sung (1982) study foreign exchange markets (where, with a few exceptions, a second-working-day rule applies). For the Vienna stock market, Gruenbichler (1991) reports anomalous seasonals that substantially exceed the effects of time value.

We first turn to the tests of settlement effects. In Section 2.2 we discuss the pros and cons of tests that rely on time series of either spot returns or forward returns, relative to tests on forward premiums. Section 2.3 introduces the way we obtain average coefficients. Results follow in Section 2.4.

2.1 The Model

Let v_t denote an unobservable true value based on full and correct use of all relevant available information, expressed as a price for immediate payment and delivery. Since neither the actual spot nor forward prices imply immediate settlement, the corresponding true "spot" and forward values, denoted as s and f, should contain a settlement effect shown below, with n_s and n_f denoting the number of calendar days to settlement and R the simple per diem interest rate. In addition, actually observed prices are assumed to deviate from true values by a zero-mean, i.i.d. noise term, denoted by ϵ_s or ϵ_f, respectively, which reflects unanticipated orders by liquidity traders and noise traders, as standard in microstructure models[7]:

$$\begin{aligned} \text{noise-free prices: } s_{t+\tau} &= (1+n_{s,t}R_t)v_{t+\tau}, & (1)\\ f_t &= (1+n_{f,t}R_t)v_t, & (2)\\ \text{observed prices: } S_{t+\tau} &= s_{t+\tau}(1+\epsilon_{s,t+\tau}) = v_{t+\tau}(1+n_{s,t}R_t)(1+\epsilon_{s,t+\tau}), & (3)\\ F_t &= f_t(1+\epsilon_{f,t}) = v_t(1+n_{f,t}R_t)(1+\epsilon_{f,t}). & (4) \end{aligned}$$

with $\mathrm{E}_{t-\Delta}(\epsilon_{s,t+\tau}) = 0 = \mathrm{E}_{t-\Delta}(\epsilon_{f,t})$; and time t is 10:00 a.m., the opening of the forward market; time $t+\tau$ is 13:00 p.m, the opening time of the spot market.

These models are not ready for use in itself as they contain unobservable prices. The standard way to make such models tractable, in the sense of being able to identify some key parameters, is to consider returns—percentage changes in S or F, as is done below. In (5) and (7), the true values have been combined into a true return, denoted as ρ_t, which is then assumed to be unpredictable white noise; we also introduce the shorthand notation $\Delta n_s R$ and $\Delta n_f R$ to indicate the settlement effect in a spot or forward returns, and e to indicated $\ln(1+\epsilon)$. Thus, for the spot market we have

$$\begin{aligned} r_{s,t+\tau} &:= \ln\left(\frac{S_{t+\tau}}{S_{t+\tau-1}}\right), \\ &= \ln\left(\frac{1+n_{s,t}R_t}{1+n_{s,t-1}R_{t-1}}\right) + \ln\left(\frac{v_{t+\tau}}{v_{t+\tau-1}}\right) + \ln(1+\epsilon_{s,t+\tau}) - \ln(1+\epsilon_{s,t+\tau-1}), & (5)\\ &=: \Delta(n_s R)_t + \rho_{t+\tau} + e_{s,t+\tau} - e_{s,t+\tau-1}, & (6) \end{aligned}$$

[6]See *e.g.* Lakonishok and Levi (1982), Jaffe and Westerfield (1985).

[7]We ignore the time value of half a day as interest is calculated per entire day only.

and likewise, in the forward tier,

$$
\begin{aligned}
r_{f,t} &:= \ln\left(\frac{F_t}{F_{t-1}}\right), \\
&= \ln\left(\frac{1+n_{f,t}R_t}{1+n_{f,t-1}R_{t-1}}\right) + \ln\left(\frac{v_t}{v_{t-1}}\right) + \ln(1+\epsilon_{f,t}) - \ln(1+\epsilon_{f,t-1}), && (7) \\
&=: \Delta(n_f R)_t + \rho_t + e_{f,t} - e_{f,t-1}. && (8)
\end{aligned}
$$

2.2 Competing Test Equations for Settlement Effects: pros & cons

We consider four test equations, each with its pros and cons. The first two are our earlier expressions for the spot and forward returns, Equations (6) and (8). The third test equation is the difference of the returns which, because of the overlap in the afternoon, boils down to the difference between the two morning returns (10:00-13:30). The fourth focuses on the forward premium, $\ln(F/S)$, and is obtained by subtracting the two log-price equations, the logs of (3) and (4):

$$
\begin{aligned}
r_{s,t+\tau} &= \Delta(n_s R)_t + \rho_{t+\tau} + e_{s,t+\tau} - e_{s,t+\tau-1}, && (9) \\
r_{f,t} &= \Delta(n_f R)_t + \rho_t + e_{f,t} - e_{f,t-1}, && (10) \\
r_{f,t} - r_{s,t+\tau} &= [\Delta(n_f R)_t - \Delta(n_f R)_t] + [\rho_t - \rho_{t+\tau}] + [e_{f,t} - e_{f,t-1}] - [e_{s,t+\tau} - e_{s,t+\tau-1}], \\
&= [\Delta(n_f R)_t - \Delta(n_f R)_t] + [\rho_t^m - \rho_{t+1}^m] + [e_{f,t} - e_{f,t-1}] - [e_{s,t+\tau} - e_{s,t+\tau-1}], && (11) \\
p_t &:= \ln\left(\frac{F_t}{S_{t+\tau}}\right) = \ln\left(\frac{1+n_{f,t}R_t}{1+n_{s,t}R_t}\right) + \ln\left(\frac{v_t}{v_{t+\tau}}\right) + e_{f,t} - e_{s,t+\tau}, \\
&= \Delta_t(n_s^f R) - \rho_{t+1}^m + e_{f,t} - e_{s,t} && (12)
\end{aligned}
$$

where r is the observed return (or percentage price change, including any coupon detached between $t-1$ and t); $\Delta(nR_t)$ is the theoretical settlement effect in the left-hand-side variable;[8] ρ_t and $\rho_{t+\tau}$ are the one-day true returns and ρ_t^m is the true return in the morning (10:00 a.m—13:30 p.m); and e_t the percentage noise added in the time-t price. One can, therefore, regress each of the left-hand-side variables on its associated theoretical time values and test for a unit regression coefficient, treating both the true return and the micro-structural noise

[8] Specifically, for the spot returns $\Delta n_s R_t$ equals $\ln[(1+n_{s,t-1}R_{t-1})/(1+n_{s,t}R_t)]$ where $n_{s,t}$ is the number of calendar days between dat t and the settlement date, and R_t the per diem interest rate. For forward rates the definition is analogous. For forward premiums, it equals $\ln[(1+n_{f,t}R_t)/(1+n_{s,t}R_t)]$.

Table 4: **Variability of the Time to Settlement over a Representative Two-week Trading Period**

	mon	tue	wed	thu	fri	mon	tue	wed	thu	fri	stdev
n_s	3	3	5	5	5	3	3	5	5	5	
n_f	16	15	14	13	12	9	8	7	6	5	
Δn for regressee r_s	−2	0	2	0	0	−2	0	2	0	0	1.33
Δn for regressee r_f	11	−1	−1	−1	−1	−3	−1	−1	−1	−1	3.92
Δn for regressee r_f-r_s	13	−1	−3	−1	−1	−1	−1	−3	−1	−1	4.64
Δn for regressee p	13	12	9	8	7	6	5	2	1	0	4.42

Key The table refers to two normal trading weeks. Line one shows the number of calendar days to settlement in the spot market: three in the beginning of the week, jumping to five as of Wednesday because a weekend intervenes. Line 2 shows time-value days forward, relative to the settlement date which is on Wednesday in week 3. Lines 3 and 4 show $n_t - n_{t-1}$, which is the sequence of time-value days in a series of spot and forward returns, r_s or r_f. Lines 5 and 6 show the time value days in a series of return differences and in a series of forward premiums p.

terms as regression error.[9]

One possible objection against the first and second test equation is that expected true returns should be higher, on average, in periods with high risk-free rates, which would introduce some correlation between noise and the regressor and, therefore, bias the slope coefficient upward if $\triangle n_f > 0$ and downward if $\triangle n_f < 0$. We provide an upper bound on this effect in the Appendix I, where we conclude the bias must be trivial.

A second issue is statistical power, with as its two prime determinants the variances of the regressor and of the regression error term. Most of the variability in the regressor, a time-value effect, stems from the ever-changing number of days to settlement. Table 4 shows how, over one two-week period, the days to delivery evolve in each market (lines 1-2) and what the resulting time-to-settlement pattern is in spot and forward returns. Obviously, working with spot returns provides far less power than with forward returns where, for about the same error variance,[10] the regressor has a standard deviation that is about three times higher. But either method suffers from an extra source noise, as the regression error comprises not only the two pricing errors but also the one-day true return.

[9]Note, in passing, that because of the absence of market makers, every price is not a firm quote but a number that is the stochastic outcome of an auction or call. The usual arbitrage one sees in currency markets are not possible here because there are no firm quotes. The only type of arbitrage that can (and should) occur is when market orders are placed; then the choice of the market should be based on the expected prices to be produced by the opening call.

[10]as far as we can judge from the preliminary tests.

In the next test equation, the difference-of-return equation (11), the regressor has an even better variability than the forward-return regression, as one can see in Table 4. If prices had ben synchronous, there would have been no true return in the regression either. In reality, the timing difference means that there are two true morning return items in the residual, and whether this is better than one full-day return is far from obvious. Moreover, this difference-of-returns test involves four pricing errors instead of two besides the two true return terms, and has more missing observations: we lose any day where either a spot or a forward price is missing, contemporaneous or lagged once. The last test equation (12) seem to have it both ways: only a half-day true return shows up in the error term, and the regressor has very good variability (see also Table 4). Consequently, the forward-premium test equation dominates the difference-of-returns version in that it involves just two price error terms plus one true morning return and generates fewer missing data. In addition, times to maturity are well spread all over the spectrum in the former equation. For the regressions based on r_f or $r_f - r_s$, in contrast, there is a low-variability sample most of the time, interrupted by a big outlier at the change of the *quinzaine* which provides a very influential subsample of just about 192 observations, about 10 percent of the total. Yet using forward premiums instead of returns is not the perfect solution either. Relative to the return-based regressions the drawback is that it uses cross-market information, postulating that time value is taken into account to the same extent in the two markets; the spot- or forward-return-based tests obviously do not need that. Since no equation clearly dominates on all counts, we report results for both returns and forward premiums.

2.3 Aggregated Estimates

In testing for settlement effects (or for integration and price leadership, for that matter) we first consider individual estimates. But we also want to look at aggregate or average results. For one, aggregate results provide summary measures on, for example, the settlement effect for the entire forward-spot Brussels Stock Exchange (the macro level) or for meaningful subgroups, like turnover-based portfolios.[11] An additional motivation for macro inference is that individual estimates are often noisy and imprecise. Therefore, the test results from aggregate data could support or complement the individual tests. For example, if most individual estimates are significant, aggregate estimates are expected to be so too, but the aggregate can be significant

[11] Thanks to Pierre Hillion for this suggestion.

even when most individual estimates are not. In this sense, we investigate a kind of average of the estimates.

One question that arises in this connection is the heterogeneity among the estimates of the individual series. According to Pesaran and Smith (1995), there are four procedures that can be used to estimate this average effect: the mean group estimator (estimating separate regressions for each group and averaging the coefficients over groups), pooled regression, aggregate time-series regressions, and cross-section regressions on group means. In the static case, where the regressors are strictly exogenous and the coefficients differ randomly and are distributed independently of the regressors across groups, all four procedures provide a consistent and unbiased estimate of the coefficient means (Zellner, 1969). The aggregate time-series regression procedure involve averaging data over groups into a portfolio. This procedure is not suitable for our data because too many observation is lost during the aggregation. Since, in each of the settlement-effect tests, the regressors are identical across stocks, the independence condition is obviously met; so a panel data procedure for estimating the average effects is justified here. For time value estimation in our studies, the aggregation estimate in principle equals the average of the individual ones, since individual regressions have the same regressor.

2.4 Empirical Results on Settlement Effect Tests

We report the empirical results of the single return series tests and then of the forward premiums test to estimate whether the time value is correctly reflected in prices.

From Equations (9)-(12), the settlement effect is tested for by regressing the daily spot or forward returns, or the daily forward premiums, on the corresponding time value:

$$\mathrm{E}(r_{s,t+\tau}|\Delta(n_s R)_t) = \alpha_s + \beta_s \cdot \Delta(n_s R)_t, \tag{13}$$

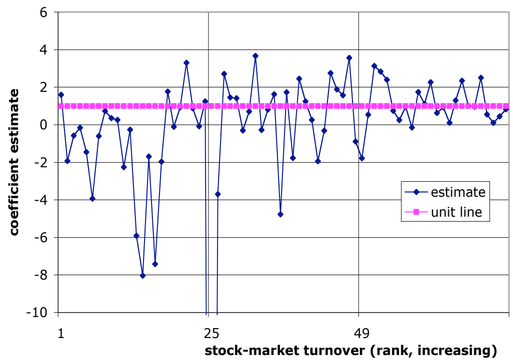
$$\mathrm{E}(r_{f,t}|\Delta(n_f R)_t) = \alpha_f + \beta_f \cdot \Delta(n_f R)_t, \tag{14}$$

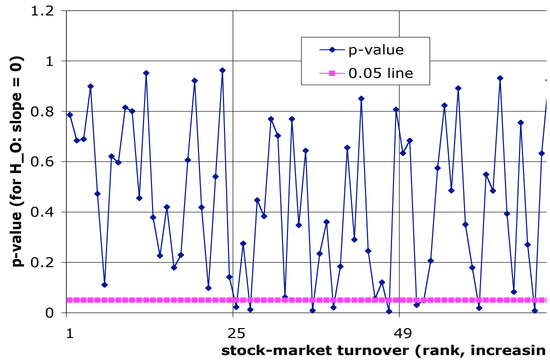
$$\mathrm{E}(p_t|\Delta_t n_s^f R) = \alpha_p + \beta_p \cdot \Delta_t(n_s^f R). \tag{15}$$

We expect a slope of unity or, if there are tax effects (10% withholding tax), a number no lower than 0.9.

The general picture is one of positive coefficients; but typically less than half of the estimates are above unity, and the aggregate coefficients are below unity. There are some surprising differences across data types, though.

Figure 2: **Time Value Coefficient Estimates and p-Values, Spot Returns**





Key Returns (spot) for 72 stocks are regressed on the theoretical time-value effect, $\Delta_t(nR)$, and we expect a slope of unity or at least 0.90. The figures show the slope estimates (to the left) and their p values (to the right). The stocks are ranked by turnover. Stock 25, whose coefficient falls outside the graph, has an outlier estimate of -66.

Table 5: **Time Value Effects in Returns and Forward premiums: selected summary statistics in single-series tests**

	# of rejections of ...				# of coefficients > 1 per (sub)sample:			
regressee	$\beta_j = 0$	$\beta_j = 1$	both	neither	all	low	mid	high
spot return	9	4	2	61	26	4	12	10
forward return	14	38	3	23	13	9	1	3
forward premium	25	36	7	18	14	9	2	3

Key Returns (spot or forward) and ex post forward premiums for 72 stocks are regressed on the theoretical time-value effect, $\Delta_t(nR)$, and we expect a slope of unity or at least 0.90. The table provides some summary statistics on the 72 slope estimates in each regression.

2.4.1 Spot returns

We start by outlining the findings. At the individual level, the settlement-effect test suggests that the time value is usually not correctly taken into account in the spot prices, but the estimation uncertainties are huge. At the macro level, *i.e.* the aggregate regression, the panel-data estimates show that the time value seems to be correctly reflected in the spot prices in the group of high-turnover stocks, but probably not in the mid-turnover group and definitely not among the thinly-traded stocks. However, also because of low variation in the regressor, the estimates are very imprecise in the total group and the three subgroups. Actually, even the total absence of any attention to time-value factors is statistically acceptable for the groups of low- and medium-turnover stocks.

Here are the details that support the above claims. The results for the equation-by-equation tests in the spot market are summarized in Figure 2 and in the leftmost and top panels of

Table 6: **Time Value Effects in Returns and Forward premiums: aggregates**

sample	single time-series $\hat{\beta}$			panel estimation of $\hat{\beta}$				Wald Test - Null: Slope=1		
(by turnover)	avge	median	$n_{>1}$	$\hat{\beta}$	SE($\hat{\beta}$)	t-stat	prob	F-stat	d.o.f.	prob
spot returns: $\mathrm{E}(r_{s+\tau} \vert (\Delta_t n_s R) = \alpha + \beta \cdot \Delta_t(n_s R)$										
All	-0.72	0.67	26	0.44	0.67	0.66	0.5113	0.68	(1, 95589)	0.4093
Low turnover	-1.06	-0.22	4	-0.68	0.74	-0.92	0.3584	5.16	(1, 27574)	0.0231
Medium	-2.16	1.03	12	0.56	0.71	0.79	0.4275	0.38	(1, 31167)	0.5363
High	1.07	0.94	10	1.19	0.77	1.55	0.1223	0.06	(1, 36846)	0.8077
forward returns: $\mathrm{E}(r_f \vert (\Delta(n_f R)_t) = \alpha + \beta \cdot \Delta(n_f R)_t$										
All	0.55	0.27	13	0.29	0.16	1.81	0.0702	19.64	(1, 87549)	0.0000
Low turnover	1.01	0.56	9	0.47	0.22	2.14	0.0320	6.05	(1, 21684)	0.0139
Medium	0.17	0.14	1	0.23	0.18	1.27	0.2042	18.81	(1, 29195)	0.0000
High	0.45	0.23	3	0.24	0.19	1.27	0.2034	16.94	(1, 36668)	0.0000
forward premiums: $\mathrm{E}(\ln(F/S)_t \vert (\Delta_t(n_s^f R)) = \alpha + \beta \cdot \Delta_t(n_s^f R)$										
All	0.29	14	0.44	0.41	0.09	4.74	0.0000	44.79	(1, 76670)	0.0000
All	0.44	0.29	14	0.41	0.09	4.74	0.0000	44.79	(1, 76670)	0.0000
Low turnover	0.85	0.66	9	0.56	0.16	3.54	0.0004	7.87	(1, 18009)	0.0050
Medium	0.15	0.36	2	0.43	0.10	4.16	0.0000	31.58	(1, 25829)	0.0000
High	0.33	0.21	3	0.33	0.10	3.19	0.0014	41.89	(1, 32830)	0.0000

Key Returns (spot or forward) and ex post forward premiums for 72 stocks are regressed on the theoretical time-value effect, $\Delta_t(nR)$. We do this for the entire sample (72 stocks), and then for three subsamples ('low', 'medium', 'high') of stocks arranged by average daily turnover.

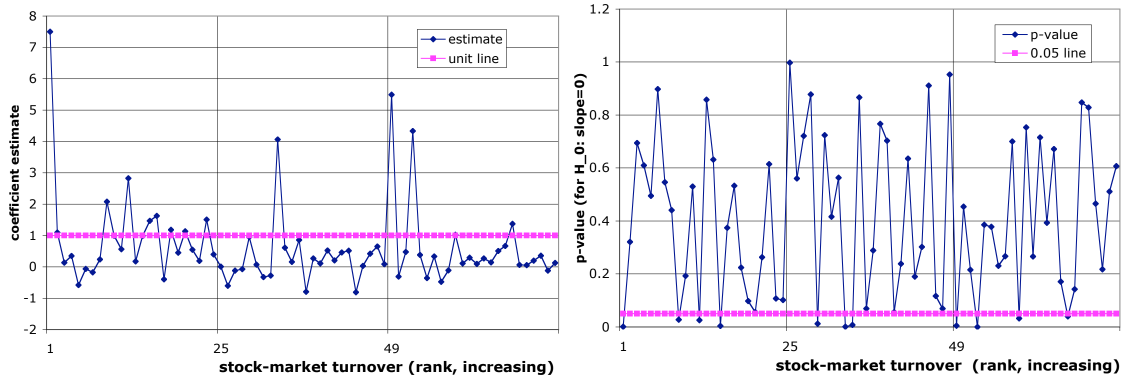
Tables 5 and 6.[12] Some of the news is quite good. Out of 72 coefficients, 26 exceed unity; in the mid- and high-turnover samples the figures are even 12/24 and 10/24, and the medians for these groups are very close to unity. But all this is overlaid by a pattern of very noisy estimates that exhibit a big negative skewness. Stock 25, in the mid-turnover group, achieves an incomprehensible estimate of –66, producing a sub-sample mean of –2.16 against a median of 1.03. Only for the high-turnover group, skewness does not seem a problem. Imprecision is huge. No less than 61 stocks out of 72 accept both a zero and a unit value for the coefficient.[13] Only nine reject a zero value, and four a unit value; of these, two reject both.

The imprecision problem is our prime motivation for adding aggregate estimates. With regard to the macro inference, the panel data estimates in the middle columns of in Table 6 shows that aggregates turn out to give less weight to the negative individual estimates, meaning

[12] In Figure 2, and in similar figures below, estimates per stock are plotted for stocks ranged by turnover rate. For visibility, the dots are linked by line segments, but any similarity to a time-series plot is unintended.

[13] All significance statements in this paper are at the 5% level, one-sided.

Figure 3: **Time Value Coefficient Estimates and p-Values, Forward Returns**



Key Returns (forward) for 72 stocks are regressed on the theoretical time-value effect, $\Delta_t(nR)$, and we expect a slope of unity or at least 0.90. The figures show the slope estimates and their p values. The stocks are ranked by turnover.

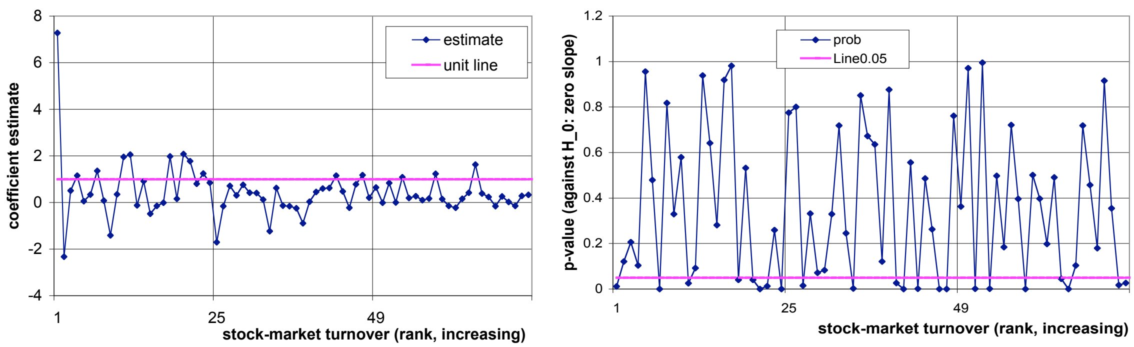
that these were deemed to be very noisy; the resulting estimates are, roughly speaking, between the unweighted means and the medians. The time value coefficient is insignificantly positive in the pooled sample of all 72 stocks and all the three subsamples; except for the the low-turnover group, the coefficient estimate is, in addition, not significantly different from unity. As for the other two groups, time value has no statistically significant impact on returns and, for the low-turnover stocks, its slope coefficient is definitely not equal to unity either. We conclude that, generally, and with the notable exception of most active stocks, the time value effect was not taken into account in the spot prices.

2.4.2 Forward returns and forward premiums

The results for forward premiums and forward returns are similar. Also in these data the general picture is one of coefficients that are positive but below unity, as we substantiate below. An expected finding is that precision is up, especially for forward premiums. Unexpectedly, however, relative to results from spot returns, medians and general averages are generally lower except for low turnover stocks (which, admittedly, did very badly in the spot-return-based tests); and medium turnovers and especially the active stocks do worse in this test than low turnover stocks. Lastly, there is right-skewness rather than left-skewness. Let us consider the evidence behind these claims.

Out of the total 72 stocks, the number of series that accept both a unit and a zero slope value falls from 61 (r_s) to 23 (r_f) and 18 (p). The number of stocks that reject both a zero and

Figure 4: **Time Value Coefficient Estimates and p-Values, Forward premiums**



Key Realized forward premiums for 72 stocks are regressed on the theoretical time-value effect, $\Delta_t(nR)$, and we expect a slope of unity or at least 0.90. The figures show the slope estimates and their p values. The stocks are ranked by turnover.

a unit slope rises from 2 to 3 or 7. All this suggests better precision, as expected given the clearer signals.

More precision should mean more significantly non-zero results, everything else being the same. The number of rejections of a zero slope rises from 9 to 14 (r_f) or even 25 (p). One would expect that these clearer signals also to be reflected in prices to a larger extent than the feeble signals that are present in spot markets; that is, also coefficients should rise. Yet this turns out to be too optimistic. Most of the estimates are positive indeed, but the number of slopes above unity has shrunk from 26 (spot returns) to 13 (forward returns) or 14 (premiums). Relatedly, more stocks—38 or 36, up from 4—now reject a unit slope. Average and median slopes are down in all samples except the small-volume group. Curiously, in light of the spot-return results and intuition, low-turnover stocks actually do best now: most above-unity slopes now are low-turnover stocks (9/13 for r_f, 9/14 for p instead of 4/26 for r_s). This is also reflected in the averages and medians of the single-series estimates: these look impressively close to unity for low-turnover stocks, and then fall if we go higher on the turnover scale.

As for the macro analysis, the panel data estimation in Table 6 shows that except for the mid- and high-turnover groups in the forward return test, time value is definitely a factor in all the remaining six cases: each of the six coefficient estimates is significantly positive. Yet, they now also all reject a unit slope statistically, and even the best numbers are farther below unity than what we saw in spot data. Third, again confirming the results from individual regressions and contrasting with the findings from spot data, the highest aggregate coefficient is for the low-turnover group, with the lowest for the medium- (r_f) or the high-turnover stocks (p).

To sum up: In the spot market we actually see very little evidence in favor or against a time-value effect. In the forward markets, where the time value signals should be stronger, we do find that time value affects prices, but the effect is substantially smaller than what theory predicts. As expected, the estimate from the forward premiums provides the cleanest results, but even there the estimates remain below our theoretical priors—and, indeed, below the results for forward returns. In the next section, we question the hypothesis of market efficiency, where the forward premiums are unpredictable.

3 Autocorrelation in the Price Discrepancies

Let us define the settlement-corrected forward price and premium as follows:

$$F'_t := F_t \frac{1 + n_{s,t} R_t}{1 + n_{f,t} R_t}, \tag{16}$$

$$p'_t := ln \frac{F'_t}{S_{t+\tau}}, \tag{17}$$

$$= -\rho^m_{t+1} + e_{f,t} - e_{s,t}. \tag{18}$$

As of now, the prime refers to the time-value-corrected version, p'.

In our proposed model for the efficient markets, we assume that the true return ρ and the noises ϵs are unpredictable. This hypothesis means that the the premium p' should have zero autocorrelation. We now examine the autocorrelation of the forward premium.

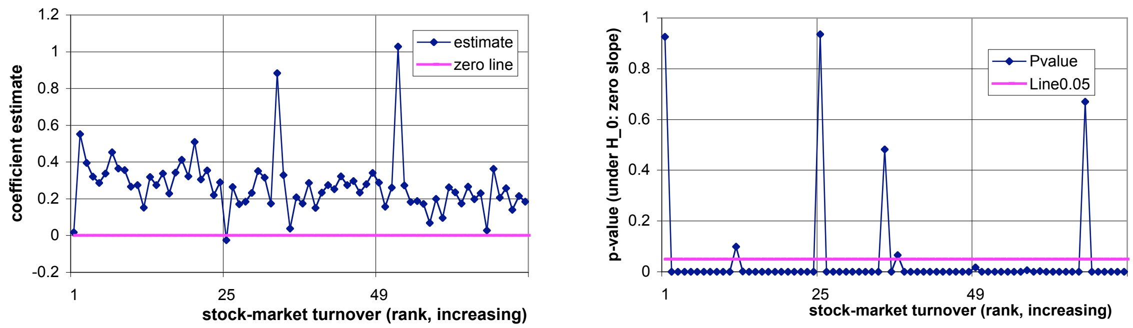
3.1 Autocorrelations in Forward premiums

Figure 5 summarizes the autocorrelation of forward premium for the individual stock estimates visually, while Table 7 provides some numerical information. The obvious feature is that autocorrelation is positive. Out of the total 72 cases, only one estimate actually is negative, and only marginally so, while 66 cases or 91.7% of the estimates are significantly positive. The averages and the number of significant rejections tend to fall the more active the stock is, but the effect is quite slight: the general average coefficient is 0.27, falling from 0.32 to 0.24 as we go from thinly to actively-traded stocks; the medians are similar.

For aggregates obtained via panel regression we test the independence assumption by regressing, for every equation, the 72 slopes on the corresponding turnovers. For the sample as a whole there is, unsurprisingly, a significant negative relation, but within turnover groups there

Figure 5: **Autocorrelation in the Forward premiums, Stock by Stock.**

$$\mathrm{E}_{t-\Delta}\left(\frac{F_t'-S_t}{S_{t-1}}|S_{t-1},F_{t-1}'\right)=\gamma_0+\gamma_1\frac{F_{t-1}'-S_{t-1}}{S_{t-1}}$$



Key Ex post forward premiums for 72 stocks are regressed on their lagged value. This slope, γ_1, estimates the scaled autocovariance of the forward premiums. A zero γ_1 means that forward premiums are not correlated, a positive one signals positive autocorrelation in premiums, meaning that the true-morning-return is also autocorrelated of first-order. We show estimated gammas and their p-values for all stocks, arranged by daily average turnover.

Table 7: **Test of Autocorrelation in the Forward premiums.**

$$\mathrm{E}_{t-\Delta}\left(\frac{F_t'-S_t}{S_{t-1}}|S_{t-1},F_{t-1}'\right)=\gamma_0+\gamma_1\frac{F_{t+1}'-S_{t-1}}{S_{t-1}}$$

sample	individual series estimation					panel estimation			
(by turnover)	mean	median	$n_{>0}$	sgnf$_{>0}$	sgnf$_{<0}$	$\hat{\gamma}_1$	SE(.)	t-stat	prob
All	0.27	0.26	71	68	0	0.29	0.011	25.33	0.0000
Low turnover	0.32	0.32	24	23	0	0.32	0.022	14.30	0.0000
Medium	0.26	0.26	23	22	0	0.27	0.016	17.08	0.0000
High	0.24	0.20	24	23	0	0.26	0.012	21.50	0.0000

Key Ex post forward premiums for 72 stocks are regressed on their lagged value. A zero γ means that forward premiums are not correlated, a positive one signals positive autocorrelation in premiums, meaning positive autocorrelation in the true-morning return. We show summary statistics for all stocks and for three subsamples of stocks arranged by daily average turnover.

is no more clear link (Table 8). The aggregates are very similar to the straightforward means of individual estimates, and are clearly different from zero. All this implies that the forward premium is predictable, which is a sign of inefficiency—for example, a differentially slow dissemination of the fundamental information for at least one day[14]. This phenomenon occurs across the entire spectrum of trading volume. So, the question is what prevented traders from making use of the predictability in the forward premiums.

[14]Autocorrelation in the true morning returns could be a source of autocorrelation in price discrepancies, but it is almost unthinkable, in an efficient market, that the true returns could generate daily autocorrelation of 0.3. Also, se see no such high autocorrelation in either spot or forward returns.

Table 8: **Preparing for Panel estimation: Independence Tests for Slopes**

	regressing γ_j on turnover			regressing δ_j on turnover		
	slope	t-stat	prob	slope	t-stat	prob
All	-1.80	-2.63	0.0104	-15.10	-5.87	0.0000
Low turnover	2.96	0.10	0.9199	-142.38	-2.07	0.0505
Medium	12.35	1.90	0.0707	-84.63	-3.07	0.0057
High	-0.37	-0.40	0.6943	-2.97	-0.82	0.4207

Key γ_1 estimates the scaled autocovariance of forward premiums. To be able to estimate the mean gamma via panel regressions with a common slope we need to test that individual stocks' gammas are deviating randomly from a general mean. Here we test whether there is a relation with turnover, first in the all-stock sample and then in the three subsamples of stocks assembled on the basis of average daily turnover.

3.2 Event Study Test: a Sign-related Asymmetry

In this part, we search for an explanation for the high autocorrelations. Problems in shorting in the spot market could be a candidate. If this is the case, then, upon bad news, spot prices would be slower to react than forward prices (where shorting is very easy). Thus, upon bad news, the ratio of forward over spot prices would be temporarily depressed, meaning that negative p's would tend to persist for some time. Positive p's, in contrast, should disappear overnight as buying spot is no more difficult than buying forward.

We test this via an event study. Table 9 shows average abnormal forward premiums in the period of 1 to 10 days after an 'event', with the event being defined as a forward premium exceeding, respectively, 2, 3, or 4 percent (positive events) or falling below -2, -3, or -4 percent (negative events).

The result is that, after negative mispricing irrespectively of the size, the next-day abnormal premium was close to zero. The result for positive premiums is different: conditional on an unusually high initial forward premium, it takes several days for the abnormal premium to decay towards zero. Typically, one-third of a large positive premium is still there the next day, against about one-tenth for negative outliers. The phenomenon of conditional autocorrelation is most pronounced with the less active stocks. This is exactly the opposite of what one would expect when shorting is difficult. An additional striking fact is that positive extreme events are more than twice as frequent as negative ones.

Clearly, then, the problem is not so much that shorting the stock is difficult in the spot market. Rather, a desire to economize on cash seems to be at the root of the persistent discrepancies. In a setting where, sufficiently often, the marginal agents are cash-strapped,

Table 9: **Average Abnormal Forward premiums: Event Study**

		positive events										
>2%	# of events	Day 0 (%)	Day 1 (%)	Day 2 (%)	Day 3 (%)	Day 4 (%)	Day 5 (%)	Day 6 (%)	Day 7 (%)	Day 8 (%)	Day 9 (%)	Day 10 (%)
All	3435	2.38	0.94	0.71	0.65	0.51	0.56	0.53	0.48	0.49	0.48	0.52
Low turnover	1450	2.42	1.22	0.95	0.94	0.64	0.69	0.64	0.61	0.59	0.67	0.60
Medium	1127	2.38	0.83	0.65	0.56	0.46	0.53	0.49	0.42	0.54	0.45	0.59
High	858	2.35	0.79	0.53	0.45	0.44	0.46	0.47	0.43	0.36	0.32	0.36
>3%	# of events	Day 0 (%)	Day 1 (%)	Day 2 (%)	Day 3 (%)	Day 4 (%)	Day 5 (%)	Day 6 (%)	Day 7 (%)	Day 8 (%)	Day 9 (%)	Day 10 (%)
All	1324	3.42	1.19	0.82	0.61	0.64	0.73	0.58	0.49	0.58	0.54	0.50
Low turnover	662	3.45	1.50	0.99	0.89	0.84	1.01	0.83	0.83	0.76	0.76	0.67
Medium	377	3.40	1.40	0.89	0.55	0.69	0.85	0.51	0.37	0.65	0.52	0.38
High	285	3.42	0.70	0.56	0.39	0.38	0.32	0.38	0.24	0.32	0.31	0.43
>4%	# of events	Day 0 (%)	Day 1 (%)	Day 2 (%)	Day 3 (%)	Day 4 (%)	Day 5 (%)	Day 6 (%)	Day 7 (%)	Day 8 (%)	Day 9 (%)	Day 10 (%)
All	1055	5.30	1.30	0.99	0.78	0.74	0.70	0.64	0.61	0.64	0.63	0.62
Low turnover	612	5.46	2.13	1.44	1.23	1.05	1.07	1.05	0.77	0.97	0.90	0.88
Medium	320	5.25	1.20	0.97	0.79	0.69	0.62	0.42	0.65	0.51	0.34	0.49
High	123	5.16	0.53	0.51	0.29	0.44	0.36	0.44	0.39	0.37	0.63	0.48
		negative events										
<-2%	# of events	Day0 (%)	Day1 (%)	Day2 (%)	Day3 (%)	Day4 (%)	Day5 (%)	Day6 (%)	Day7 (%)	Day8 (%)	Day9 (%)	Day10 (%)
All	1542	-2.42	-0.18	0.07	0.16	0.31	0.17	0.29	0.23	0.14	0.26	0.22
Low turnover	519	-2.42	-0.20	0.10	0.35	0.46	0.40	0.46	0.25	0.38	0.37	0.35
Medium	568	-2.42	-0.20	0.17	0.16	0.36	0.10	0.17	0.24	-0.01	0.25	0.23
High	455	-2.40	-0.14	-0.05	-0.02	0.10	0.01	0.24	0.22	0.07	0.18	0.09
<-3%	# of events	Day0 (%)	Day1 (%)	Day2 (%)	Day3 (%)	Day4 (%)	Day5 (%)	Day6 (%)	Day7 (%)	Day8 (%)	Day9 (%)	Day10 (%)
All	547	-3.41	-0.45	-0.01	0.07	0.17	0.06	0.01	0.11	0.22	0.20	0.26
Low turnover	192	-3.42	-0.52	0.01	0.13	0.36	0.19	0.16	0.11	0.59	0.51	0.43
Medium	249	-3.38	-0.48	0.19	0.03	0.21	0.24	-0.23	0.06	-0.11	0.21	0.24
High	106	-3.44	-0.34	-0.25	0.03	-0.09	-0.24	0.08	0.17	0.12	-0.17	0.11
<-4%	# of events	Day0 (%)	Day1 (%)	Day2 (%)	Day3 (%)	Day4 (%)	Day5 (%)	Day6 (%)	Day7 (%)	Day8 (%)	Day9 (%)	Day10 (%)
All	442	-5.21	-0.47	-0.06	0.23	-0.09	0.31	0.32	0.25	0.17	0.15	0.29
Low turnover	193	-5.28	-0.79	-0.26	0.46	-0.29	0.62	0.27	0.35	0.34	0.09	0.69
Medium	192	-5.26	-0.33	0.05	0.10	-0.16	0.11	0.58	0.16	0.07	0.23	0.18
High	57	-5.07	-0.20	0.07	0.08	0.26	0.12	0.10	0.25	0.05	0.14	-0.09

Key We show the average realized forward premium on days 1, ... 10 following an event, the event being defined as a forward premium (shown on the column for day 0) exceeding either 2, 3 or 4% or below either –2, –3 or –4%. We expect a zero mean, in well-integrated and well-functioning markets. 'All' refers to all stocks; 'Low', 'Medium' and 'High' refer to subsamples of 24 stocks each, assembled on the basis of average daily turnover.

buyers would prefer the forward market while sellers would go for a spot sale. This would then imply patterns of persistently high forward prices, relative to spot values. It would also explain why these occurrences are so much more frequent than instances of very low prices.

4 Conclusions

Both spot and forward tiers of the BSE fail to always reflect the correct time value effect: in the spot tier, the time value effect is insignificant, while in the forward tier the (traces of) time value effects are limited to low-volume stocks. Additionally, a close look at the price discrepancies reveals that borrowing restrictions or other problems with quickly raising liquidities could be a reason for the autocorrelation: negative *ex post* premiums vanish overnight (on average), and the positive premiums are much more frequent and, on average, persistent. This pattern is consistent with a cash scarcity problem, steering buyers to the levered forward market and sellers to the spot tier, rather than with problems in shorting stocks in the cash market.

Appendix I: Evaluating the Potential Bias in the Time-Value Tests

One possible objection against the standard regression test for time value effects is that true returns should be higher, on average, in periods with high risk-free rates, which would then introduce some correlation between noise and the regressor and hence bias the coefficient upward.

However, due to low variation of the risk-free rate, the bias is negligible, as proved below. In the regression of forward rate $r_{f,t}$ on the time value $\Delta n_{f,t} R_t$, where $\Delta n_{f,t} = (n_{f,t} - n_{f,t-1})$, is

$$r_{f,t} = \alpha + \beta * \Delta n_{f,t} R_t + \rho_t + e_{f,t} - e_{f,t-1}. \tag{19}$$

with $(\rho_t + e_{f,t} - e_{f,t-1})$ being the residual. The bias is introduced by the correlation between the true return ρ_t and the risk-free rate R_t:

$$\begin{aligned} bias = \widehat{\beta} - \beta &= \frac{\mathrm{cov}(r_{f,t}, \Delta n_{f,t} R_t)}{\mathrm{var}(\Delta n_{f,t} R_t)} - \beta \\ &= \frac{\mathrm{cov}(\rho_t, \Delta n_{f,t} R_t)}{\mathrm{var}(\Delta n_{f,t} R_t)} \\ &= \frac{\mathrm{E}(\Delta n_{f,t})}{\mathrm{var}(\Delta n_{f,t} R_t)} * corr(\rho_t, R_t)\sqrt{\mathrm{var}(\rho_t)\mathrm{var}(R_t)} \end{aligned} \tag{20}$$

In the extreme case, *i.e.* $corr(\rho_t, R_t) = 1$, the highest magnitude of bias is $\frac{\mathrm{E}(\Delta n_{f,t})}{\mathrm{var}(\Delta n_{f,t} R_t)} * \sqrt{\mathrm{var}(\rho_t)\mathrm{var}(R_t)}$. We can roughly calculate the following numbers from the data:

$\mathrm{E}(\Delta n_{f,t})$:	-9.640E-04
$\mathrm{var}(\Delta n_{f,t} R_t)$:	1.E-06
$sqrt\mathrm{var}(R_t)$:	6.79E-05

So the maximum bias is $-0.65456 * \sqrt{var(\rho_t)}$, with ρ_t being not higher than the observed prices, *i.e.* spot prices. Taking Delhaize stock in the studied period as an example, the standard deviation of the spot prices was 0.012, which makes the maximum bias -0.000785472. This negligible bias makes interpretation of the OLS estimates in the single-market series plausible.

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